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POLICY PERSPECTIVE

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Conserving European biodiversity across realms

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Abstract

Terrestrial, freshwater, and marine ecosystems are connected via multiple biophysical and ecological processes. Identifying and quantifying links among ecosystems is necessary for the uptake of integrated conservation actions across realms. Such actions are particularly important for species using habitats in more than one realm during their daily or life cycle. We reviewed information on the habitats of 2,408 species of European conservation concern and found that 30% of the species use habitats in multiple realms. Transportation and service corridors, which fragment species habitats, were identified as the most important threat impacting ~70% of the species. We examined information on 1,567 European Union (EU) conservation projects funded over the past 25 years, to assess the adequacy of efforts toward the conservation of "multi-realm" species at a continental scale. We discovered that less than a third of multi-realm species benefited from projects that included conservation actions across multiple realms. To achieve the EU's conservation target of halting biodiversity loss by 2020 and effectively protect multi-realm species, integrated conservation efforts across realms should be reinforced by: (1) recognizing the need for integrated management at a policy level, (2) revising conservation funding priorities across realms, and (3) implementing integrated land-freshwater-sea conservation planning and management.

KEYWORDS
Birds Directive, conservation planning, EU Biodiversity Strategy, funding priorities, Habitats Directive, integrated management, multi-realm species, Red List, threats

1 | INTRODUCTION

Recent research has highlighted the importance of identifying and quantifying links among the terrestrial, freshwater, and marine realms when planning for conservation and managing ecosystems (e.g., Álvarez-Romero et al., 2011; Saunders et al., 2017). Multiple biophysical and ecological processes connect realms, allowing for the movement of species and the transfer of energy and matter across them (Beger et al., 2010). Concurrently, there are numerous cross-realm threats to ecosystems, such as agricultural effluents impacting freshwater and marine ecosystems (Álvarez Romero et al., 2011). Thus, the persistence of species in one realm can be jeopardized by human activities occurring in another (Stoms et al., 2005). To avert such risks, threat management and prioritization of conservation actions require an integrated approach spanning all realms (Adams et al., 2014; Saunders et al., 2017; Tallis, Ferdaña, & Gray, 2008).

The need for integrated conservation efforts is further pronounced when dealing with organisms that use habitats in more than one realm during their daily activities or life cycle (hereafter referred to as multi-realm species). For example, diadromous fishes that migrate between freshwater and marine ecosystems, and dragonflies that move daily between freshwater and terrestrial ecosystems. Identifying connections between ecosystems within different realms is critical for the persistence of multi-realm species. For migratory animals, such as several shorebird species, these connections can extend over broad spatial scales and cross borders (Iwamura et al., 2013), making international collaboration necessary to ensure cross-boundary species conservation (Kark et al., 2015).

Despite this, connections among realms have been broadly ignored when managing ecosystems and conservation efforts have mainly focused on one particular realm (Álvarez-Romero et al., 2011, 2015). This is partly because collaboration between the various governmental and nongovernmental organizations that are responsible for the implementation of management actions in different realms is poor (Álvarez-Romero et al., 2015; Reuter, Juhn, & Grantham, 2016). Consequently, some threatened multi-realm species have only been protected in one realm that is associated with one stage of their life or daily cycle. For example, most conservation efforts targeting sea turtles have primarily focused on protecting nesting sites on land (Mazor, Beger, McGowan, Possingham, & Kark, 2016). Although such conservation initiatives have been successful, the current decrease of some sea turtle

populations (e.g., Eastern and Western Pacific leatherbacks) may be associated with the challenge of protecting these species across their habitats (Klein et al., 2017; Mazaris, Schofield, Gkazinou, Almpanidou, & Hays, 2017). Likewise, conservation efforts for wetland-breeding amphibians that focused on wetlands without considering adjacent terrestrial habitats have been ineffective (Dodd & Cane, 1998).

Moreover, the lack of coordinated conservation actions across political boundaries has often been an obstacle in conserving effectively threatened species including multi-realm species (Dallimer & Strange, 2015, Runge et al., 2015). Barriers to international collaboration can be removed when countries coordinate their conservation efforts through intergovernmental institutions, such as the European Union (EU), which funds and supports trans-national conservation initiatives across Europe. The EU has set policy targets to halt and reverse the loss of biodiversity by 2020 (EC, 2011). Although the EU´s 2020 Biodiversity Strategy is explicitly linked to fisheries, agricultural, and forestry policies, the integration of these policies and thus the explicit consideration of connections among realms is still lacking. Key steps toward the effective conservation of multi-realm species, in Europe and elsewhere, include the identification of multi-realm species, the assessment of their threats, and the evaluation of funding dedicated to cross-realm conservation actions as a measure of adequacy at covering the special needs of the species.

2 | IDENTIFYING MULTI-REALM SPECIES OF EUROPEAN CONSERVATION CONCERN AND THEIR THREATS

We reviewed information on the habitats of 1,124 threatened species in Europe, that is, species classified in the European Red List (up to April 2016) with one of the following categories: Critically Endangered (CR), Endangered (EN) or Vulnerable (VU), to identify multi-realm species (see Appendix S1 and Table S1). Funded by the EU since 2006, the European Red List is compiled by the IUCN's Global Species Programme, in collaboration with experts. The list identifies those species that are threatened with extinction at the European level, so that appropriate conservation action can be taken to improve their status. Additionally, we reviewed information on the habitats of 1,284 non-threatened species that are listed in the EU Habitats (92/43/EEC) and Birds (2009/147/EC) Directives. Threatened species listed in the Directives are also included in the European Red List, thus, information on these species had already been reviewed. The two directives are the cornerstones of Europe's nature conservation policy and guide the designation of the EU wide Natura 2000 network of protected areas. Species listed in their annexes should receive protection or be maintained in a favorable conservation status. Major threats for each multi-realm species were identified by accessing the IUCN Red List of Threatened Species database.

Nearly a third ($n = 778$) of the species of European conservation concern assessed were multi-realm species, belonging to 3 plant and 15 animal taxonomic groups (Appendix S1). Species living in ecosystems at the intersection of multiple realms, for example, vascular plant species in estuaries, were also identified as multi-realm species. The largest group of multi-realm species were birds (37%; $n = 289$), with the vast majority of them (89%) being identified as migratory birds. Freshwater molluscs were the second largest group ($n = 171$) followed by vascular plants ($n = 98$). More than half of the multi-realm species (62%) depend on terrestrial and freshwater habitats ($n = 481$), 10% depend on terrestrial and marine habitats ($n = 79$), and 8% require freshwater and marine habitats ($n = 65$). About 20% of the species ($n = 153$) depend on habitats across all three realms.

A large number of multi-realm species were subject to common threats. Roads and other "transportation and service corridors" impacted approximately 70% of the species (Table S2). Other major threats were "energy production and mining" (affecting 56% of the species), "agriculture and aquaculture" (56%), and "invasive and other problematic species, genes and diseases" (47%).

3 | ASSESSING EUROPEAN INVESTMENT IN MULTI-REALM SPECIES CONSERVATION

Several funding sources are available to support biodiversity conservation in the EU (e.g., the European Agricultural Fund for Rural Development and the European Fisheries Fund) but only the LIFE Program earmarks funds for actions directly related to the implementation of biodiversity conservation (Kettunen et al., 2009, 2017). Consequently, LIFE has become the main financial tool for the implementation of conservation projects in Europe (Hermoso, Clavero, Villero, & Brotons, 2017). Here, we used data from LIFE-Nature projects to estimate the extent of the investment made for the conservation of multi-realm species at a continental scale. Information on each of the 1,567 LIFE-Nature projects that were funded during the period 1992–2016 was sourced from https://ec.europa.eu/environment/life/. We identified all the projects with at least one multi-realm species as a beneficiary. Projects were further analyzed only when they included explicit conservation actions in multiple realms or interface habitats, that is, habitats in the intersection of realms (Table S1), because we considered that these projects are more likely to conserve effectively the species in the highly human-dominated EU environment. Acknowledging that some multi-realm species may face threats in a single realm, we repeated

the analysis with all projects targeting multi-realm species, including projects whose actions were confined to a single realm.

Less than one third ($n = 537$) of the LIFE-Nature projects covered multiple realms and incorporated any of the 778 multi-realm species we identified. Moreover, within those 537 projects less than 30% of these species ($n = 229$) were covered. Certain groups of multi-realm species, for example, beetles, were relatively well covered whereas others, such as mammals and marine fishes, were among the least funded groups (Figure 1). In particular, multi-realm species belonging to the groups of marine molluscs, bees, grasshoppers, and medicinal plants were not covered by any LIFE-Nature project. The vast majority (91%) of the species funded under LIFE-Nature were listed in the annexes of the Habitats or Birds Directives. The species that received the largest budget for protection (~56 million euros) was the Eurasian bittern (*Botaurus stellaris* Linnaeus, 1758; Figure 2). This species was funded almost twice as much as the second most funded species, the Atlantic salmon (*Salmo salar* Linnaeus, 1758). The Eurasian bittern is listed as a priority species for funding under the LIFE program but has an IUCN conservation status of "Least Concern (LC)."

In fact, more than half of the LIFE-Nature projects' budget (61%) was allocated to species classified as "LC" (Figure 3a). Although the average budget allocated to threatened species belonging to the categories "EN" and "VU" was higher than the one allocated to non-threatened species (Figure 3b), the vast majority of projects targeted very few "CR" multi-realm species and focused on "LC" species (Figure S2). Only 7% of multi-realm "CR" species received funding, whereas funds were allocated for the conservation of 41% of the "LC" species. About 65% of the projects benefiting a single species ($n = 115$) targeted non-threatened species.

Species that depend on terrestrial and freshwater habitats, representing 61% of the multi-realm species assessed herein, received about 80% of the total budget (Figure 3c). On average, the 118 funded species belonging to this realm combination received ~3.9 million euros. Species requiring freshwater and marine habitats ($n = 18$) on average received larger budgets in comparison to species related to other realm combinations (Figure 3d). However, more than half the budget (57%) was dedicated to only two fishes, *S. salar* and *Alosa fallax* (Lacepède, 1803). Species depending on terrestrial and marine habitats ($n = 21$) received on average the smallest budget, equivalent to ~2.2 million euros. Nearly one-third of the total budget for this realm combination was allocated to the loggerhead sea turtle (*Caretta caretta* Linnaeus, 1758), which is a priority species for funding under the LIFE program.

Even when considering all projects targeting multi-realm species ($n = 753$), including those projects whose actions were confined to a single realm, the percentage of multi-realm species covered increased only slightly (34%). The total investment in multi-realm species conservation increased from around 800 million to 1.2 billion euros. The patterns of investment revealed were similar to those found when only considering projects that incorporated multiple realms, with more than half the projects' budget (57%) being allocated to species classified as "LC" (Figure S1). Species that depend on terrestrial and freshwater habitats still received the highest proportion of the total budget (51%; Figure S1).

The allocation of LIFE-Nature funds for the conservation of multi-realm species across EU member states and across realm combinations varied greatly among countries (Figure 4). In Croatia and Lithuania, more than 80% of the total LIFE funds were allocated to projects that targeted multi-realm species whereas in Cyprus, France, the Czech Republic, Italy, and the United Kingdom, the respective proportion was less than 15%. In Spain, LIFE funds dedicated to the conservation of multi-realm species for all dual realm combinations (freshwater–terrestrial, marine–terrestrial, marine–freshwater) were greater than in other member states. Species depending on habitats in all three realms received the most coverage in Sweden. Similar patterns were revealed when funds were adjusted using country-level purchasing power parity (PPP) as in Lung, Meller, van Teeffelen, Thuiller, and Cabeza (2014) (Appendix S1; Figure S3). The most remarkable difference being the substantial funds devoted in the combination of freshwater and marine ecosystems in the United Kingdom.

Overall, our findings demonstrate that (1) LIFE-Nature projects have been covering a small proportion of multi-realm species of conservation interest, (2) conservation effort is skewed toward specific taxonomic groups, and (3) species that are most in need of conservation effort receive disproportionally less funding.

4 | REINFORCING EU'S INTEGRATED CONSERVATION EFFORTS

While the scientific recognition of the need for integrated conservation across realms gains ground, the practical implementation of integrated conservation actions lags. To date, more than 800 million euros have been invested in LIFE-Nature projects targeting multi-realm species and including conservation actions across realms. Although this is a substantial contribution toward integrated conservation efforts, only 30–34% of multi-realm species of conservation concern (i.e. multi-realm species listed in the European Red List and/or in the Habitats and Birds Directives) have benefitted to date from LIFE-Nature funds. While acknowledging that other sources of funding exist and may benefit multi-realm species, the LIFE-Nature programme remains the main financial instrument for biodiversity conservation in the EU.

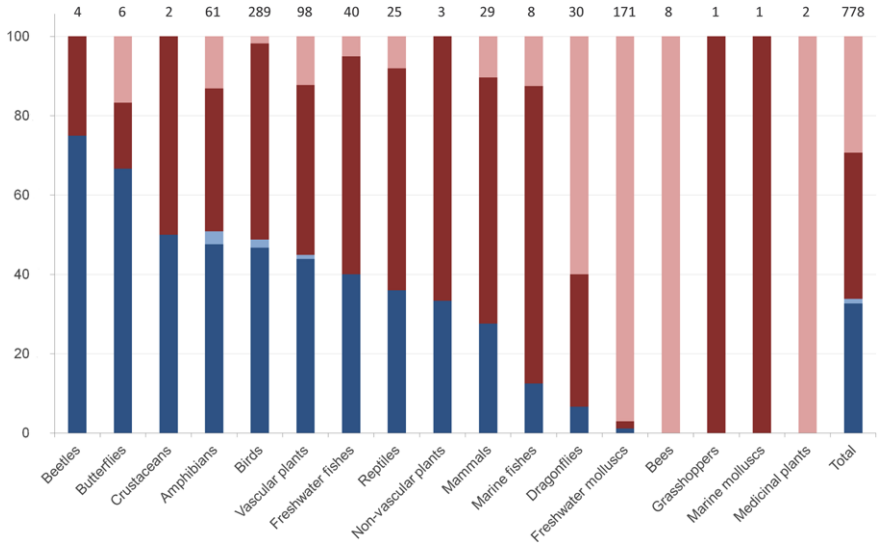

FIGURE 1 Proportion of multi-realm species within each taxonomic group targeted for conservation by at least one LIFE-Nature project in the period 1992–2016. Blue bar sections correspond to the proportion of species that have received funding from LIFE-Nature projects (dark blue: proportion of species included in the Annexes of the Birds and Habitats Directives, light blue: threatened species not included in the Annexes). Red bar sections show proportions of species that have not received LIFE-Nature funding (dark red: proportion of species included in the Annexes of the Birds and Habitats Directives, light red: threatened species not included in the Annexes). The last column refers to the total number of species identified as multi-realm species of European conservation concern. Numbers on top of the bars refer to the total number of these species in each group

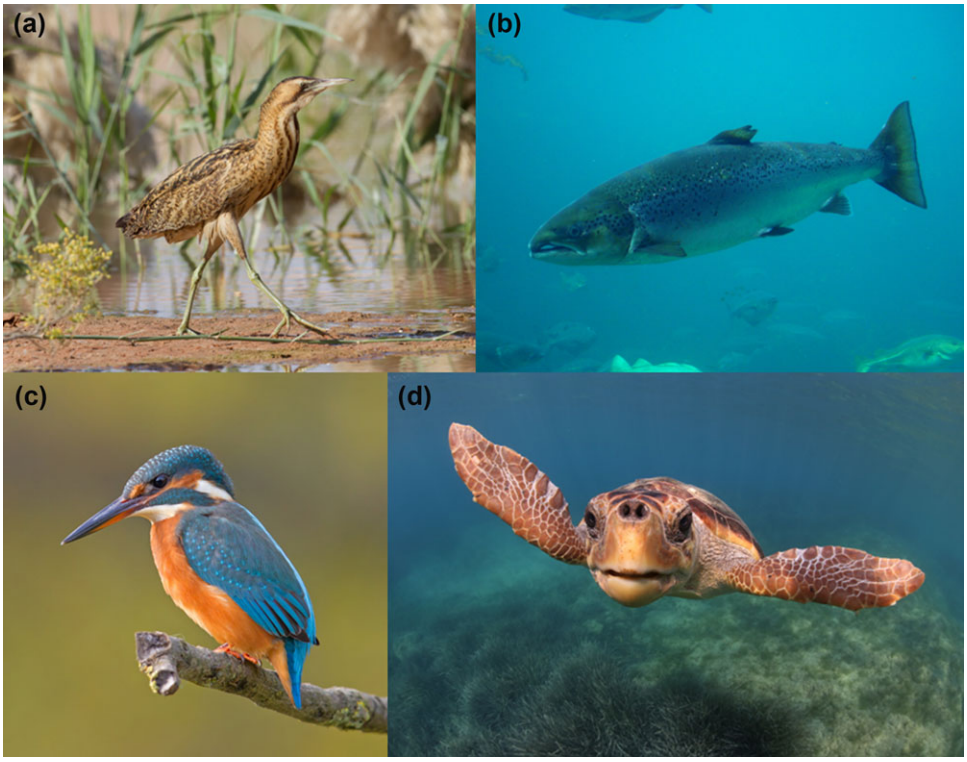

FIGURE 2 Multi-realm species that received the most LIFE-Nature funds per realm combination. The overall estimated budget allocated for the conservation of: (a) the Eurasian bittern (*Botaurus stellaris* Linnaeus, 1758), a bird species using terrestrial & freshwater habitats, was 56,363,932 euros; (b) the Atlantic salmon (*Salmo salar* Linnaeus, 1758), a marine fish using freshwater & marine habitats, was 30,607,947 euros; (c) the common kingfisher (*Alcedo atthis* Linnaeus, 1758), a bird using terrestrial & freshwater & marine habitats, was 13,921,416 euros; and (d) the loggerhead turtle (*Caretta caretta* Linnaeus, 1758), a reptile using terrestrial & marine habitats, was 11,405,033 euros. Photo credits: (a) Mike Barth, https://www.mikebarthphotography.com, (b) Hans-Peter Fjeld, (c) Andreas Trepte, (d) Konstantinos Papafitsoros

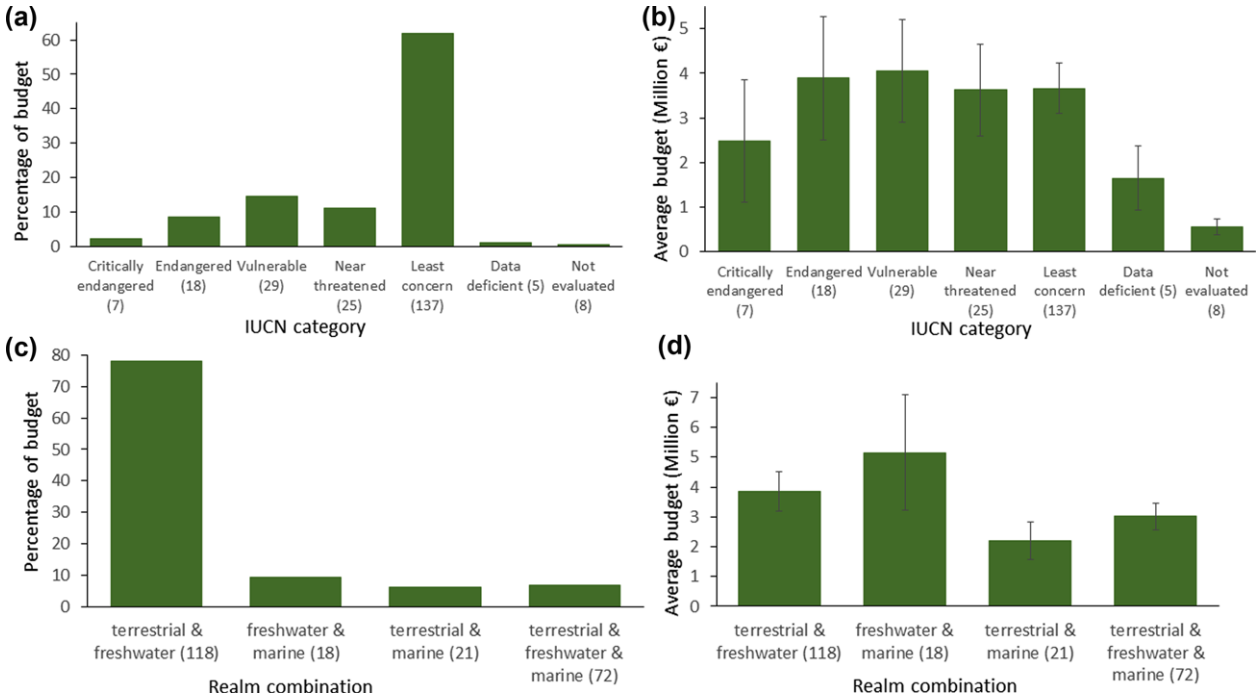

FIGURE 3 Proportion of (a, c) and average (b, d) LIFE-Nature budget of projects spent for multi-realm species in each IUCN category (a, b) and realm combination (c, d). The projects included in the analyses are those including actions in more than one realm

Species action plans and funds from national sources of member states that could contribute substantially to the conservation of multi-realm species have not been captured here. Yet, species action plans often present taxonomic bias (Sitas, Baillie, & Isaac, 2009), and nationally or locally funded actions often miss coordination at larger spatial scales, even though this is critical for ensuring the persistence of multi-realm species across national borders. The EU provides a platform to coordinate conservation efforts across borders and identifies priorities for conservation at a continental level. To reinforce integrated conservation efforts across Europe we provide the following recommendations.

4.1 | Policy recognition for the need of integrated conservation across realms

The EU, as a Party to the Convention of Biological Diversity (CBD), developed a biodiversity strategy to meet its international commitments. The EU 2020 Biodiversity Strategy is directly linked to the Common Agricultural Policy, the Common Fisheries Policy, the Water Framework Directive (2000/60/EC) and the Marine Strategy Framework Directive (MSFD; 2008/56/EC). Yet, in none of these policies are connections of species populations and human activities across realms explicitly considered. To date, most EU policy documents, such as the MSFD, refer to activities and management measures that are confined to a single realm. An exception is the recommendation of the European Parliament and of the Council for integrated coastal zone management (2002/413/EC). In this policy document, the connections among the terrestrial and marine realms are explicitly stated as well as the need for integrated management to ensure the sustainability of coastal ecosystems and their services. Furthermore, with the EU Marine Spatial Planning Directive (2014/89/EU), a framework for marine spatial planning and integrated coastal management was established which considers the interaction between land- and sea-based activities. This is an important step toward integrated conservation but coastal ecosystems are not the only systems that can benefit from integrated management and planning across realms. Adams et al. (2014) highlighted numerous benefits of applying integrated conservation planning and actions across terrestrial and freshwater ecosystems. Therefore, we recommend that policy-makers consider a broader array of ecosystems and their connections when formulating integrated management policies and strategies.

4.2 | Recurrent revision of conservation funding priorities

The first target of the EU 2020 Biodiversity Strategy is to fully implement the Habitats and Birds Directives. More specifically it is stated that: "These two Directives are the cornerstones of the EU's biodiversity policy, enabling all 27 EU member states to work together, within the same legal framework, to conserve Europe's most endangered and valuable species and habitats across their entire natural range within the EU." Yet, our findings, in accordance with evidence from

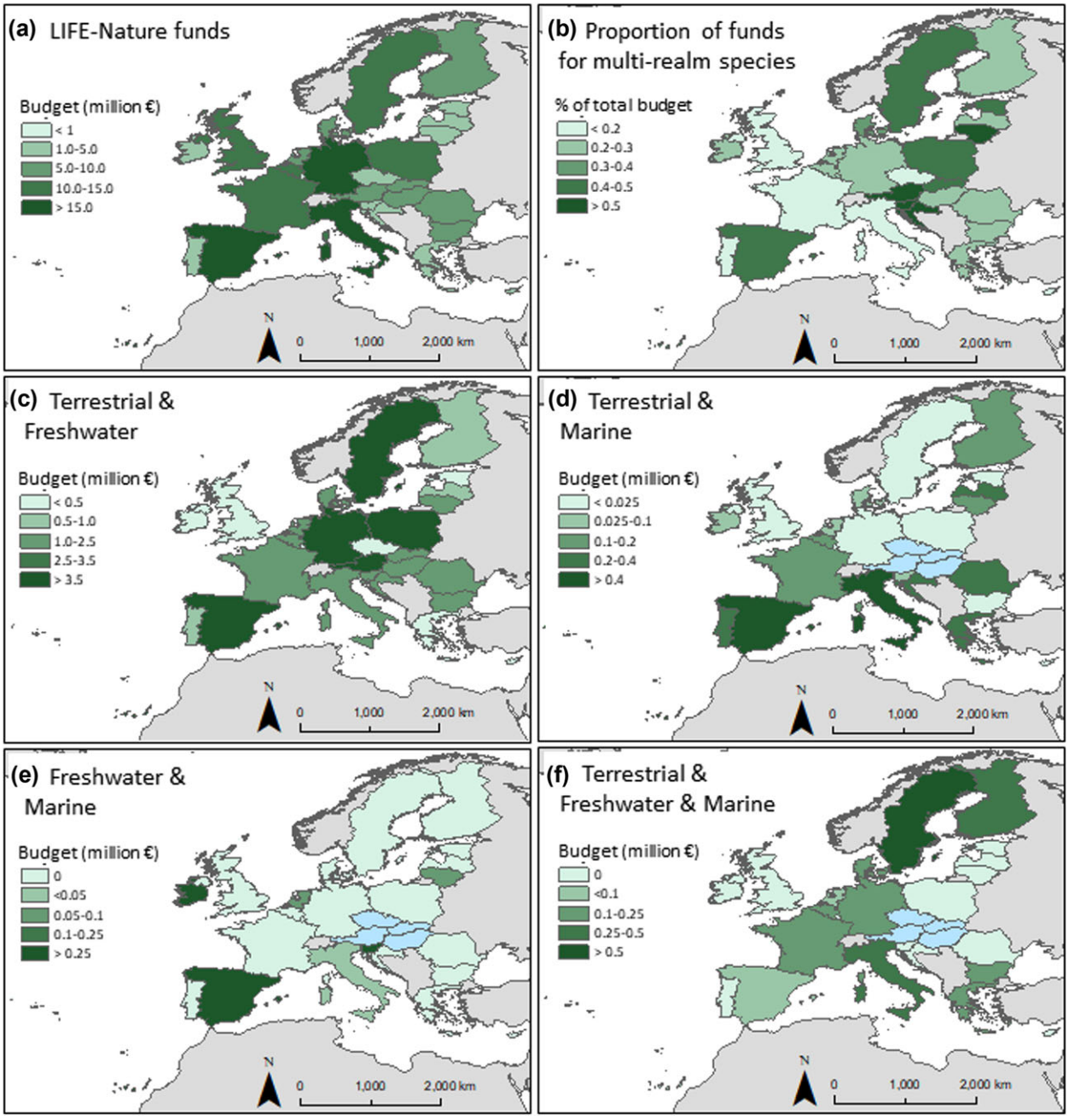

FIGURE 4 Distribution of LIFE-Nature investment across EU member states. For each member state, average investments were calculated by considering total funds received over the time period the member state was eligible for LIFE projects. Maps show distribution of (a) LIFE-Nature funds, (b) proportion (%) of LIFE-Nature funds for multi-realm species, and (c–f) LIFE-Nature funds per realm combinations (c: Terrestrial & Freshwater, d: Terrestrial & Marine, e: Freshwater & Marine, f: Terrestrial & Freshwater & Marine) across EU member states for the period 1992–2016. Landlocked countries in the realm combinations including a marine component are illustrated in light blue

previous studies (e.g., Hermoso et al., 2017; Jeanmougin, Dehais, & Meinard, 2017; Maiorano et al., 2015), demonstrate that even the full implementation of the two directives would not benefit the most endangered species. The allocation of LIFE-Nature funds has been mainly driven by the Habitats and Birds Directives but most of the species benefitting from these funds are "Least Concern" species. When considering only the species listed in the two directives, we found that funds were not allocated in respect to the species conservation status and the urgency of their conservation needs. Moreover, many threatened species included in the European Red List (as CR, EN, or VU) are missing from the directives' annexes. Therefore, we join the voices of our colleagues and call for an adaptive revision of the conservation priorities set by the two directives and their harmonization with the European Red List. Revisions should be conducted periodically to

capture the effectiveness of the actions financed by LIFE-Nature projects and other conservation funding initiatives (Hochkirch et al., 2013). Effective conservation actions may drive changes of species' status. Moreover, these periodic assessments will allow the increase or decrease of threats to biodiversity to be reflected. These changes should be taken into account when revising conservation priorities and allocating the scarce conservation resources. Funds should be prioritized but not exclusively dedicated to the conservation of threatened species as some non-threatened species play important ecological roles in ecosystem functioning and the provision of ecosystem services.

4.3 | Implementation of integrated conservation planning and management

The EU's network of protected areas, Natura 2000, aims to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under the Habitats and Birds Directives. Besides the urgent need for the revision of the species listed in the two directives, we suggest that an integrative approach is adopted when designating new Natura 2000 sites across realms. Currently, the vast majority of Natura 2000 sites that include a marine area are either extensions of terrestrial sites into the sea or cross-realm sites whose coverage is highly biased toward land (Mazaris, Almpanidou, Giakoumi, & Katsanevakis, 2017). The selection of these sites has often been driven by terrestrial rather than marine conservation needs (Giakoumi et al., 2012). Similarly, the conservation of freshwater ecosystems has been peripheral to conservation goals developed for terrestrial ecosystems (Hermoso, Abell, Linke, & Boon, 2016). Integrated conservation planning allows to meet conservation needs in multiple realms in a more balanced fashion and explicitly considers the trade-offs among alternative plans (e.g., Álvarez-Romero, Pressey, Ban, & Brodie, 2015). To effectively implement integrated conservation planning, species ranges across realms should be considered. Moreover, adopting cross-realm management actions could benefit the conservation of multi-realm species and even species whose activities are confined to one realm but face threats originating from multiple realms. Our results show that many multi-realm species face common threats, thus, mitigating the impacts of these threats may have positive conservation outcomes for many species simultaneously.

In conclusion, the EU has invested substantial financial resources on conservation projects for species that use multiple realms during their daily or life cycle. However, EU conservation efforts should be reinforced and prioritized to conserve more species that need protection across realms and that are most threatened. To do so, recognition of the need for integrated policies across realms is needed as well as the implementation of integrated conservation planning for multi-realm species.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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